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Earth Observing Satellite: Understanding the Earth as a System

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INTRODUCTORY COMMENTS

The Spirit of Discovery

While my topic is the biosphere of the Earth — Biosphere 2's big brother — my intellectual life really started with Mars. I have thought about what would be the number of a biosphere on Mars? It can't be Biosphere 3, and not infinity, because something that supported life in another solar system might be infinity. But Mars is certainly the most likely planet we know that could become a biosphere.

I will relate a story about the Viking Mission to Mars. I had a very rich experience here listening to the papers and asking questions. I am going to start by telling you that I was terribly jealous of what I saw today. I had the same impression that I had in 1961 when I first joined NASA — and that is the youthful spirit of enthusiasm that is easily recognized. It was really an exhilarating experience to suddenly find, "It feels around Biosphere 2 like it was in 1961 when the space program was just starting." One didn't care about making "mistakes". You couldn't make mistakes, you didn't even conceive of making mistakes — you went ahead and did things. Last night, Margret Augustine told me about the Institute of Ecotechnics' ship, the *R/V Heraclitus* that was raised after Hurricane Hugo sank it in San Juan harbor in September 1989. It was an extraordinary story of quick response and ingenuity in the rescue. I am afraid NASA couldn't do that today. If they did, they would do it in spite of the system, not because of the system. In a

sense, you didn't "know any better" so you just went ahead and did it. That's the story of what's happening at the Biosphere 2 project and why I and your other visitors are so in love with what they are seeing — Biosphere 2 recaptures that sensation of discovery and exploration.

My Viking story starts with the great ocean explorer Jacques Cousteau. The Viking Project was ordered to land on Mars on the 4th of July 1976, the 200th anniversary of the birth of the United States. As it happened, that date was exactly in the right window, the right several weeks during which Viking could have landed. So, of course, we planned the landing for the evening of July 4. Unfortunately, Mars didn't behave. After the spacecraft arrived at Mars on the 20th of June, we took one look at the planetary surface and I said, "There goes the ball game." There was no way it could get down on the landing site that had been selected earlier and land safely. That site was in the midst of an area of extremely steep mountains and canyons.

We suddenly realized that we had a problem on our hands. We were going to have to find a new landing site. As you know, we did find a landing site and landed two spacecraft successfully. But on the evening of June 22 we had just made the decision not to attempt a landing on the 4th of July. The project manager turned to me and said, "What are we going to do for the 4th of July. We have four hundred people from the press that are showing up at Jet Propulsion Lab. They are going to be covering something, and if we are not landing, what are we doing?" CBS, NBC, ABC all had their crews

landing site selection involved not just planetary experts, but a whole wealth of remarkable talent, sitting as we were on the doorsteps of Cal Tech.

The answer was interesting for it came from a scientist no one expected: a geochemist from Princeton who had a tiny little experiment using a magnet on the end of the Viking digging arm. Dr. Rob Hargraves' experiment was simple: to see what sticks to the magnet. Hargraves is very quiet and very smart. He had breakfast with me one day and said, "We are struggling so hard to land our spacecraft on Mars. We are counting craters, we are trying to reconstruct the history of Mars, we are looking at all the signs, we are looking at Mariner data, we are asking the Soviets...how about just finding out which way the wind blows and try to land where the soft spot is?"

It was so obvious! Every high school student could have thought of that. I said, "Have you asked the meteorologist that?" He said, "It just occurred to me." And that eventually led to the solution of the Viking landing site selection process. I was in the

right place at the right time to recognize a good idea and Rob Hargraves had the right idea.

After Viking was over, I decided that as a biologist, I was dealing with the wrong planet. As a biologist, going to Mars with life systems would be wonderful; but Mars is not the most promising place for exploration for a biologist. Its very likely from what we now know that there is no organic material on Mars. When I finished Viking, I got interested in the Earth. Recalling that marvelous experience we'd had during those intense days of looking for a landing site, I wondered about a comparable situation that affects the study of Earth. The Earth is partitioned — there are oceanographers, meteorologists, chemists, agronomists, and so on, who rarely talk to each other. When we were trying to land on Mars, everybody talked to everybody. Whether you were a meteorologist, geophysicist, you only cared that the project worked, the project was everything. That's what I see happening here at the Biosphere 2 project. It doesn't matter if you're an agronomist, engineer, entomologist, metallur-

Eos Baseline Planning Scenario

NASA POLAR PLATFORM-1 NPOP-1	NASA POLAR PLATFORM-2 NPOP-2	ESA POLAR PLATFORM-1 EPOP-1/A1	ESA POLAR PLATFORM-2 EPOP-2/B1	JAPANESE POLAR PLATFORM JPOP	NOAA FREE-FLYER	ATTACHED PAYLOADS
Orbit: 705 km Crossing: 1:30 pm Launch: 4th Qtr. 1996	Orbit: 705 km Crossing: 1:30 pm Launch: 4th Qtr. 1996	Orbit: 824 km Crossing: 10:00-10:30 am Launch: 1997	Orbit: 705 km Crossing: 10:00-10:30 am Launch: 2000	Orbit: 800 km Launch: 4th Qtr. 1996	Orbit: 824 km Crossing: 1:30 pm Launch: 1st Qtr. 1998	Orbit: 400 km Crossing: 28.5° Launch: 1st Qtr. 1998
AMS ALT GLIS HRS MODIS-N MODIS-T SRR	SAR SEM GGI GOS IPEI LIS MLS SAFIRE SWIRLS TES XIE	ATLAS SRR SRR SRR AMR CHEMISTRY RADIOMETER ALTIMETER (GPS) AMI-2 AMRH AMSU SEM ARGOS SEARCH & RESCUE	SRR SRR SRR SRR AMR CHEMISTRY STEREO IMAGER	LRR	ARGOS AMRH AMSU GOMR SEARCH & RESCUE SEM	MODIS-N MODIS-T ERBI MHR OZONE SENSOR PPS-PODS RAIN RADAR SCATTEROMETER SPECIAL IMAGER SOLAR FLIGHT OF OPPORTUNITY 1st QUARTER 1995 ACRIM SOLSTICE
CERES DLS ENAC EOSP GGI HRRS HRRLS IPEI MSR MOPITT POEMS SAGE II SCANSAT TRACER AMSU						

NASA RESEARCH FACILITY INSTRUMENT
ESA RESEARCH FACILITY INSTRUMENT
NOAA RESEARCH FACILITY INSTRUMENT
OPERATIONAL FACILITY INSTRUMENT
PI INSTRUMENT INVESTIGATIONS

Figure 2. Earth Observing Satellite (EOS) Baseline Planning scenario. (NASA)

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OF POOR QUALITY

Afterwards I had supper with Jacques Cousteau, and he talked about what he does on his research ship *Calypso*. He said most of the trained scientists aboard have a vertical view. Their job is as experts and specialists. They go into the water to investigate these specialties and every question they ask is a more profound one. Cousteau said, "I am a horizontal scanner. I am not an expert in anything. I am the person who keeps my eyes open, watches from the sides and be-

Discovery doesn't always come from vertical sounding, it also comes from horizontal perspective. As the project scientist, my job on Viking was sort of as a symphony director — you don't play anything but you are supposed to keep everybody else playing the right music. We had seventy scientific investigators on Viking. I said to Cousteau, "I loved your story, how can I ever develop this great vision that you have and ability to observe the total picture from the side." He replied, "I don't know if you have any talent in this area, but you seem to have the interest in it, so that insight will carry you a long way."

Viking was a great success, but the end of my story is this. From that evening when we first viewed the Martian surface till the spacecraft landed on July 20, a most intensive activity of

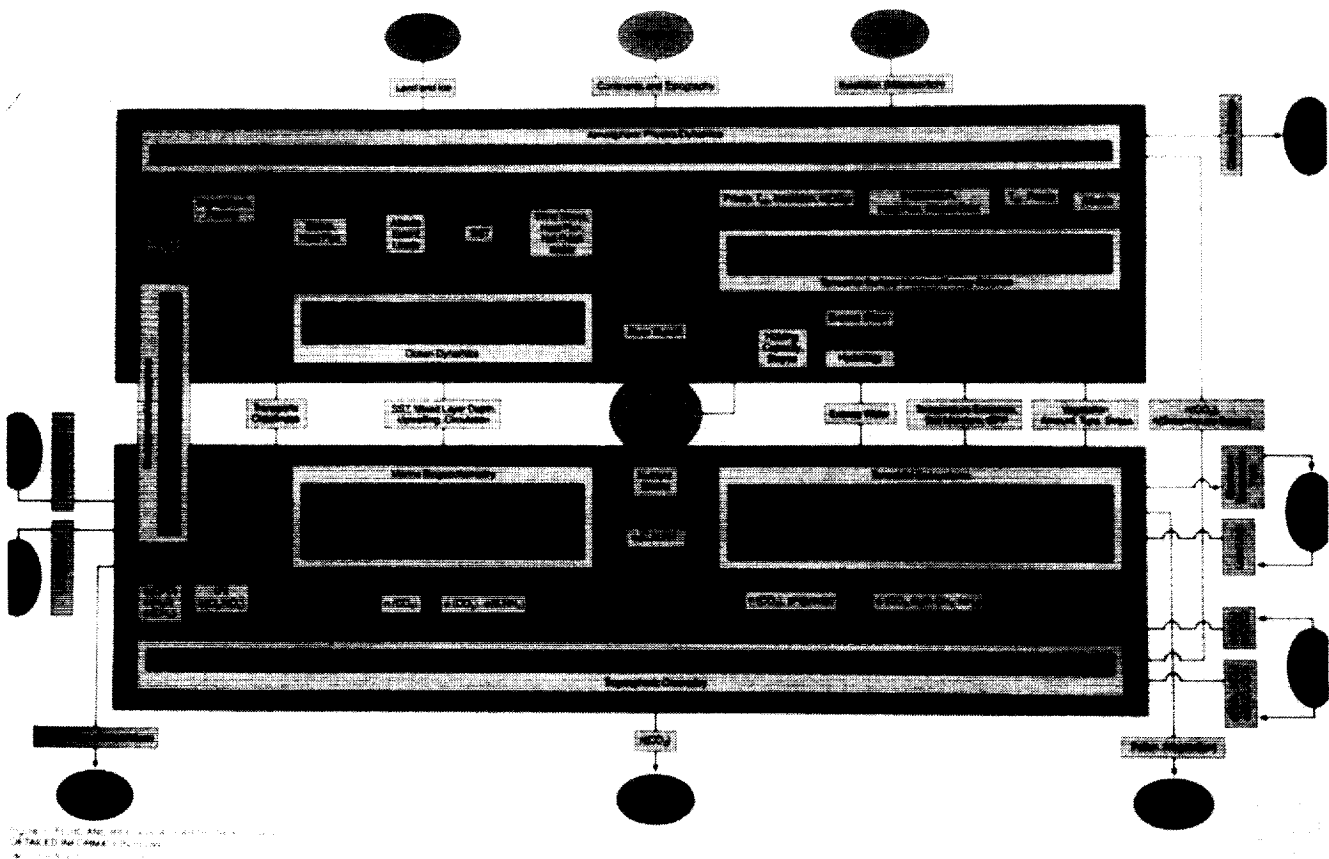


Figure 1. Fluid and biological Earth processes, detailed information flow chart. (NASA)

gist, ecologist or architect — the project is driving you together and making you think how one element affects the whole system. That spirit is what we have to achieve to preserve the Earth.

EARTH OBSERVING SATELLITE

From one perspective, the Earth Observing Satellite (EOS) came out of what we did on Mars, out of that struggle for a landing site. When I left the Mars project and reentered the "real world" at NASA Headquarters, I took a job as Director of Life Sciences. I met Dan Botkin of U.C. Santa Barbara, one of the participants at this workshop. At the time he was an advisor for the National Academy of Sciences Space Biology Board and was writing a

report on life support systems. The report talked about closed ecological life support systems and in conversations with Dan I began realizing that the ultimate life support system we know is the Earth, the global biosphere. From that came the realization that if we are ever going to do anything we had to start an effort in global ecology. We started with a program that was the predecessor to Dr. Mel Auer's program in biospherics. It was called Global Habitability — then in NASA parlance "System Z" — and has changed its names over the years but the basic concept has always been to study the Earth as a planet (Figure 1). This means to study the components of the Earth as they fit together — as you are doing in Biosphere 2 — not to go our separate ways. This is what I think hu-

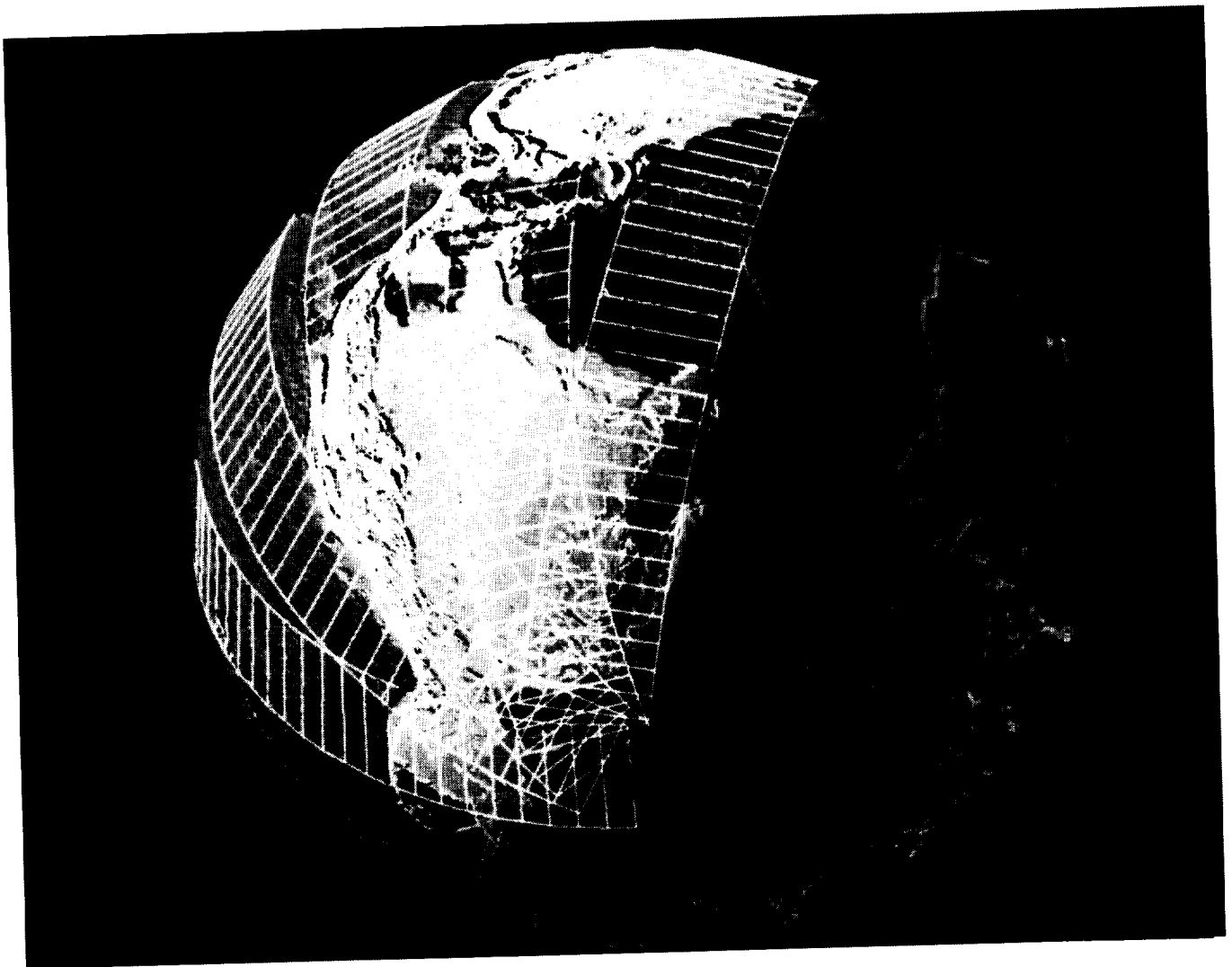


Figure 3. Earth-mapping from a polar orbiting satellite utilizes the Earth's rotation for planetary coverage. (NASA)

mankind is going to have to do if we are going to have any biological survival in the next century. We have a problem trying to communicate with and educate one another. It is almost like the Tower of Babel trying to talk together. Even many of those scientists who want to do it don't yet understand a common language, but we are learning how.

About five years ago, a group of scientists began to coin the name "Earth Systems Science". They began looking at the Earth the way an engineer might look at it, as a whole system. This is the way you look at Biosphere 2 — you see the whole system! Today we toured the heating system, the electrical system, the biological systems, the control system, etc. Similarly, we began to see how all of the Earth pieces are linked. Shortly after we started, another effort began. Partly out of alarm, partly as a result of concern about acid rain, of other global changes that were occurring, there was an attempt on a grand scale to respond.

NASA, because it is a responsive agency, volunteered. We didn't know any better so we just proceeded. Once we began to get a little attention, NOAA (National Oceanic and Atmospheric Agency) and EPA got into the act, and the next thing we had all of our political brethren down our necks saying, "Hey, you are doing our stuff. You shouldn't be doing oceanography because NOAA does oceanography, and you shouldn't be doing atmospheric studies because EPA does atmosphere." Right now the Department of Energy (DOE) is concerned because they want to do the carbon dioxide studies, since it comes from the burning of coal and oil which are energy sources. But the important issue is really not who does it, but that these important studies be undertaken.

There is now a plan for global studies which include two very large efforts. One is the International Geosphere/Biosphere Program (IGBP) sponsored by the International Council of Scientific

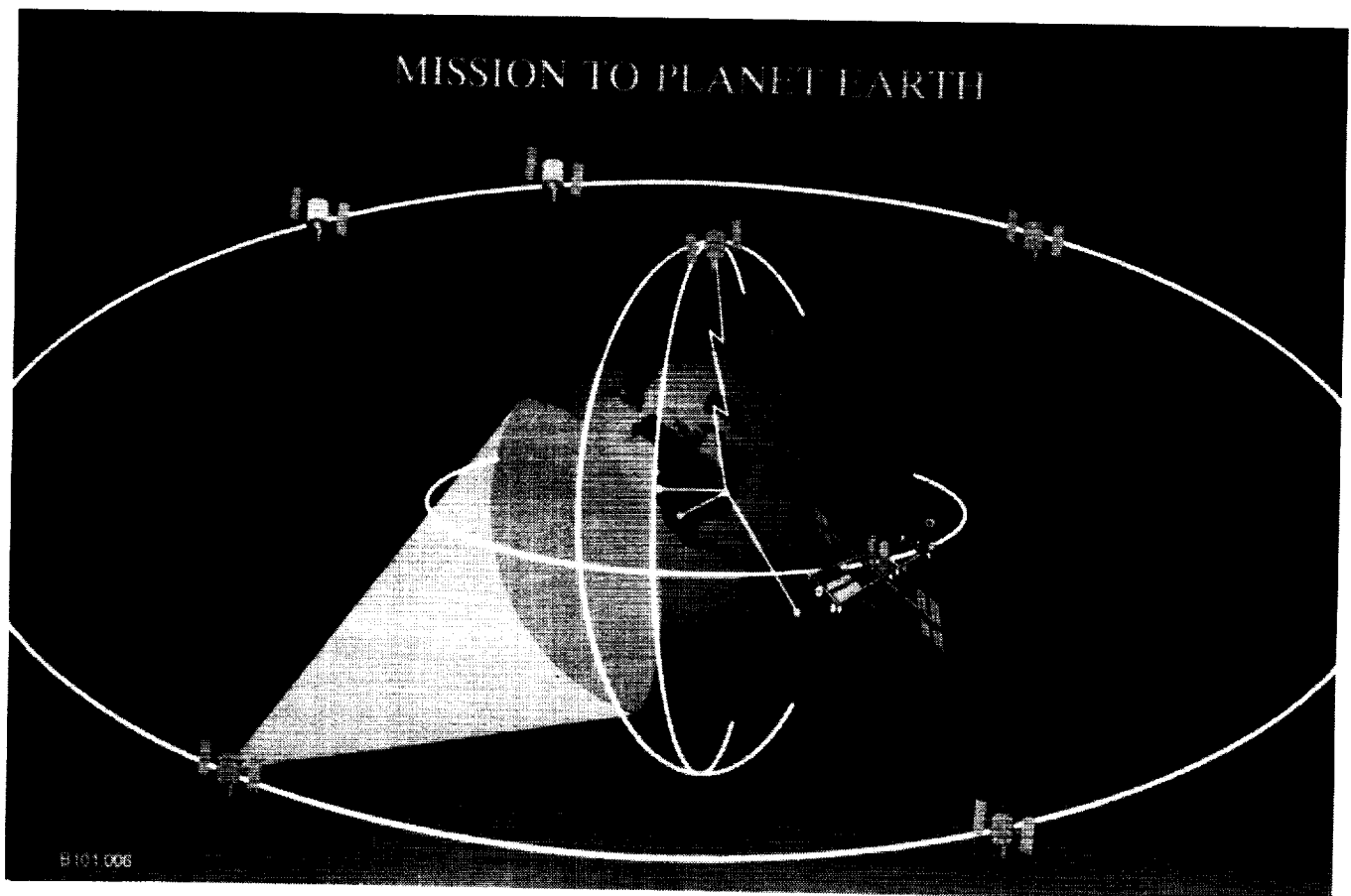


Figure 4. Schematic showing the proposed Mission to Planet Earth satellites. (NASA)

Unions. The IGBP is being discussed and planned in many countries now and is motivated by true concern and alarm about the relevant issues.

The other initiative is Mission to Planet Earth, an umbrella program for doing three kinds of space missions. The major one is the Earth Observation Satellite for which I am Project Scientist. I count this as a rare privilege, as it is rare even to get a chance to do this once. So having been Project Scientist for Viking, here I get a second opportunity. In addition to EOS, there are two complementary NASA space missions. These involve satellites in sequential orbit as a companion of *Freedom* Space Station and small satellites in geosynchronous orbit. EOS is large polar orbiting satellites with payloads weighing several thousand kilograms

and a total weight of 9000 kilograms. Two will be placed in polar orbit by NASA, one by the Japanese and one or two by ESA (European Space Agency) (Figure 2).

The beauty of a polar orbit is that by observing from pole to pole the Earth turns underneath the satellite and you get to see the entire globe (Figure 3). It lets the Earth do the work as the spacecraft orbits, obtaining fifteen passes a day of the Earth by this EOS containing about a dozen remote sensing instruments. The instruments will be different on each of the polar orbiting EOS as we are wanting to utilize some thirty instruments during the program to have a fairly complete range of sensors mapping the Earth.

There are several key points to the potential

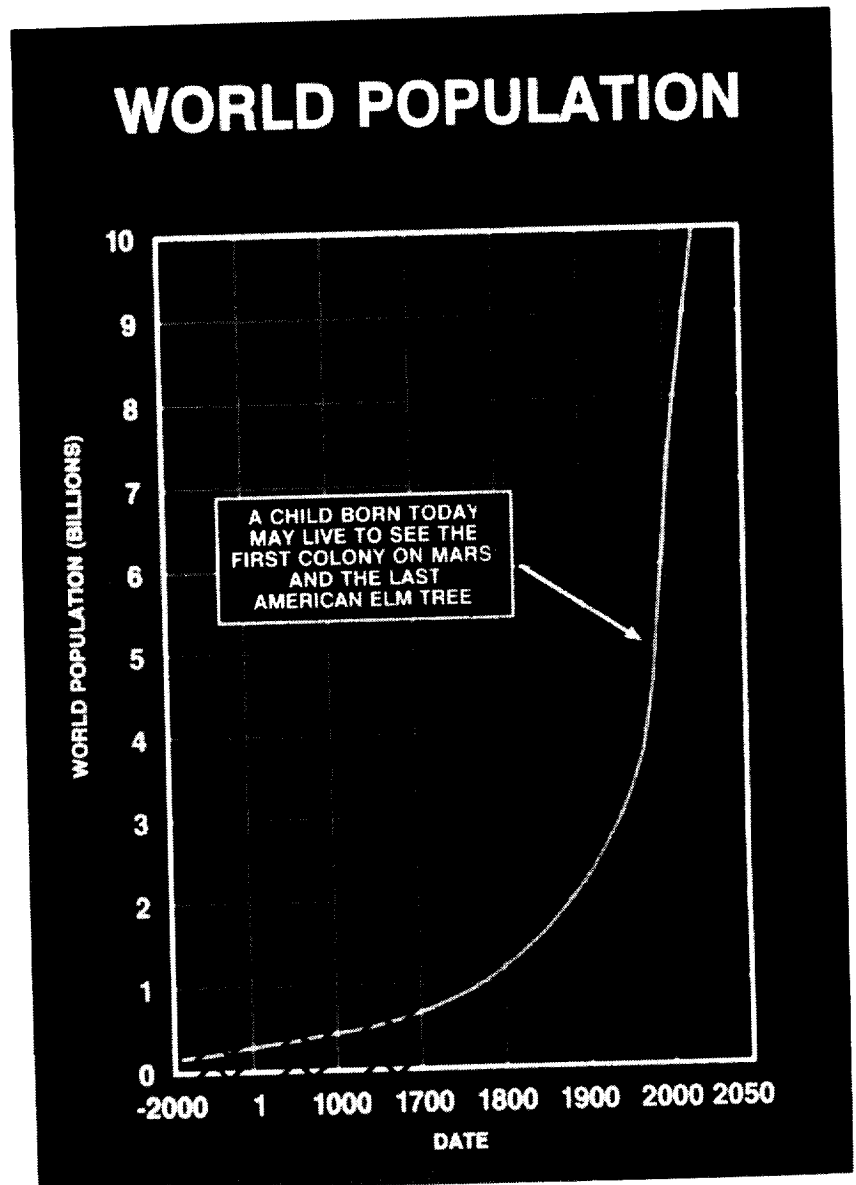


Figure 5. World Population Chart, 2000 BC to present, with human population projections to 2020 AD. (NASA)

significance of EOS. One is that EOS is not focussed on hardware, but on obtaining understanding of Earth processes. It makes a big difference if you are simply trying to launch hardware and obtain data, or whether you're trying to gain understanding. We know that we have to learn how to predict the changes occurring on the Earth. That is the objective — not simply getting more or better data. We have to learn what is causing global change. The test of understanding is prediction. For instance, can we learn to accurately predict global warming trends?

Another key issue is that there are no quick answers to these issues. Most can be answered only by statistical approaches, which require long-term data bases. The changes are subtle enough, and embedded in cycles of varying time-periods, that we must think about placing satellites in these polar orbits not for a quick look, but rather for periods of about a decade. NASA is not used to

doing that, but we are building this requirement into the program to ensure a continuous record of measurements. Why a decade? Basically that is because it is about a solar cycle of eleven years. We may eventually have to look at a longer period, but we know we get sufficient oscillations over a timeframe of one to two years that we must have a longer period. Although many people use the term "solar constant", we in fact know that it is not constant, so at least one solar cycle should be studied. This raises very interesting questions of reliability because no one has previously built spacecraft to last that long. We are currently examining two options. One is to provide servicing capability in space by replacing filters, lenses, batteries etc. by robotic or astronaut flights. The other is to send a replacement craft after 4-5 years in case the first stops operating. Our concerns are that we may spend too much money making the

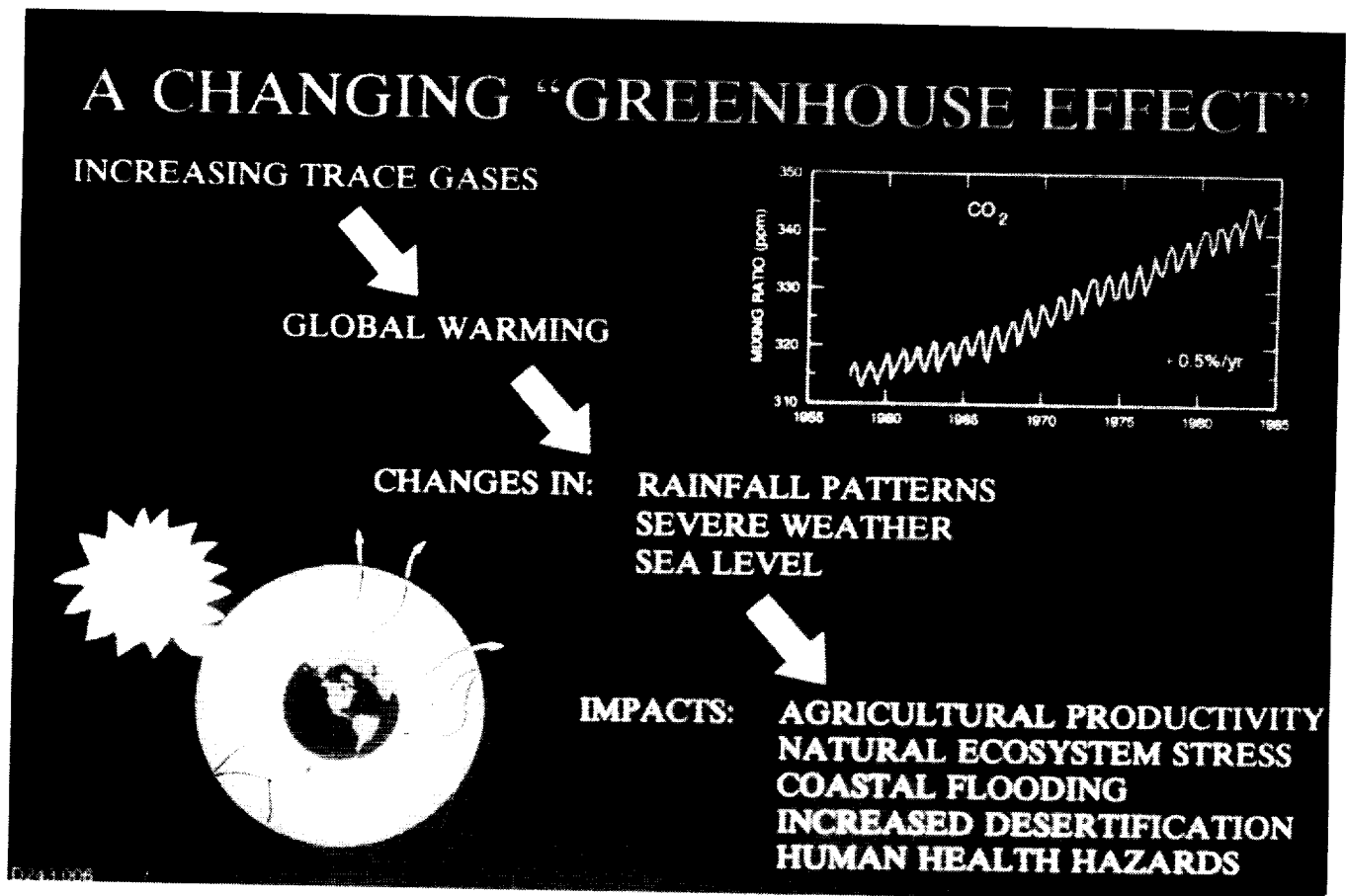


Figure 6. Carbon dioxide levels in Earth's atmosphere 1957-1985, and possible impacts on global environment. (NASA)

payload so reliable that it lasts ten years while it may become obsolete during that time-period.

Another innovative approach of the EOS program is that it is no longer adequate to simply supply the data obtained to one scientist to determine the answers. It is going to be everybody's data. Previously it was given to one scientist, the Principal Investigator, and he was expected to publish his results in due course. Once the EOS data is available, we must get it out, available to anyone who is willing to study it. It is so vital we can't stop with distributing it to just one scientist. The data belongs not only to the United States, it belongs to the world. That makes the EOS Mission different from anything we have ever done.

Another thing that makes EOS unusual is that

it is expensive, very expensive. The requirement of the decade-long operation is a factor that drives up the costs. Recently we calculated the price tag of EOS during various phases. In NASA terminology, Phase A is when you conduct a study of what needs to be done and various options are considered. Phase B is the organizational stage when you select scientists and make determinations of instrumentation. This is the phase we are currently in the midst of. The next phase, Phase C starts about a year from now, in the fall/winter of 1990. This is when expenditures really escalate. The money starts pouring out because we "cut metal", we actually "bend hardware", we really start making things. We are currently planning on spending around 1.2 billion dollars a year. That is an enor-

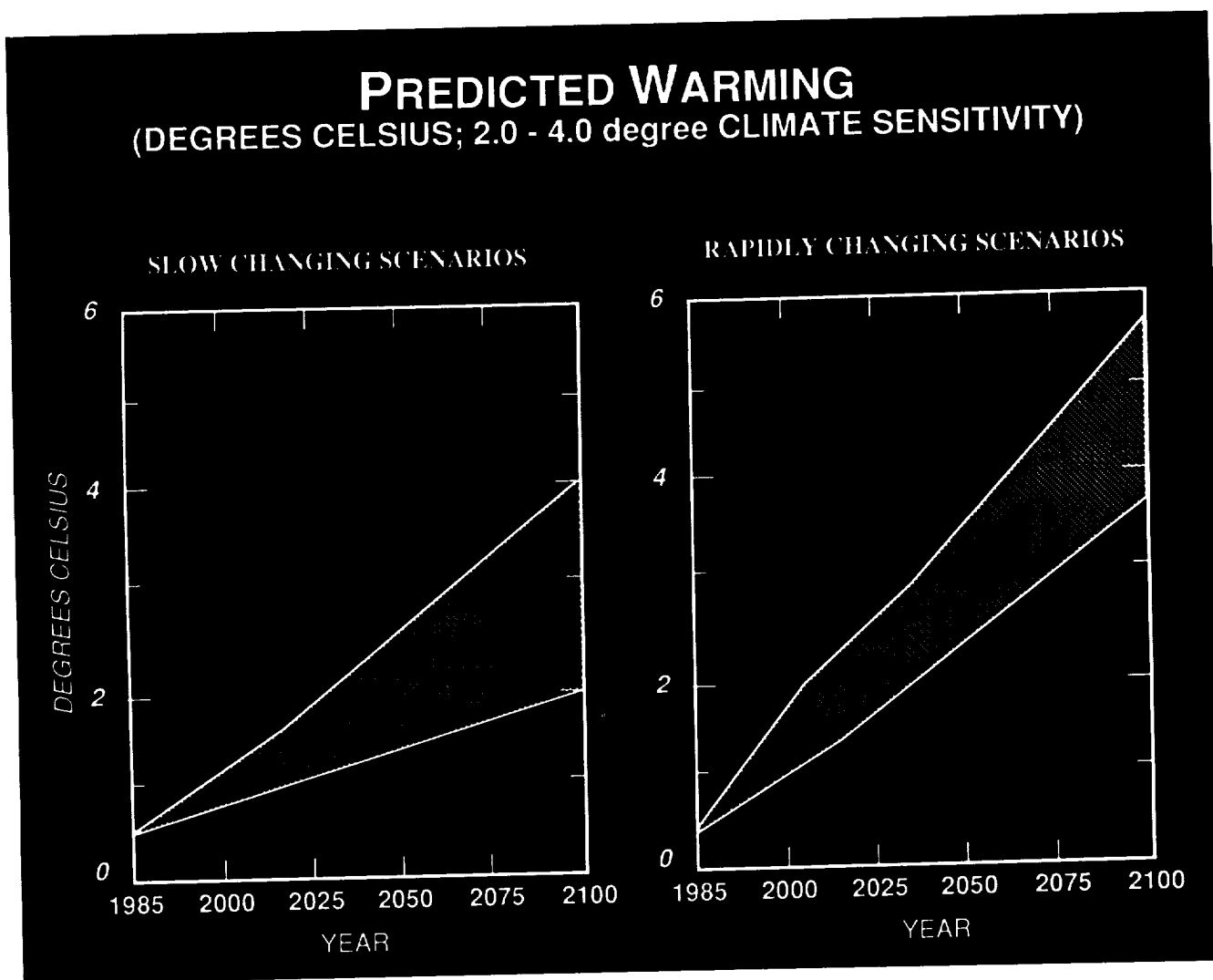


Figure 7. Predicted global warming, showing scenarios of slow and rapid change. (NASA)

mous amount of money. There will be tens of thousands of people working on this effort including engineers in many of the aerospace companies. We will operate at that level of expenditure until we launch the first EOS at the end of 1997. The second one is scheduled for launch two years later.

In conjunction with the American efforts, the Japanese and the Europeans have each committed to do one Earth Observing Satellite also. So four spacecraft — one European, one Japanese and two American — will all be up in polar orbit at the same time. Some of our instruments will be on the Japanese birds and some of the Japanese or the European instruments will be on our birds. The effort will no longer be just ours or theirs — rather, a joint effort in which nations of the world have

shared this effort and the data is going to be available to everybody. That's the heart of what EOS is about.

We can summarize the overall mission measurement objectives of EOS:

1. The global distribution of energy input to and energy output from the Earth.
2. The structure, state variables, composition and dynamics of the atmosphere from the ground to the mesopause.
3. The physical and biological structure, state, composition and dynamics of the land surface, including terrestrial and inland water ecosystems.
4. The rates, important sources and sinks, and

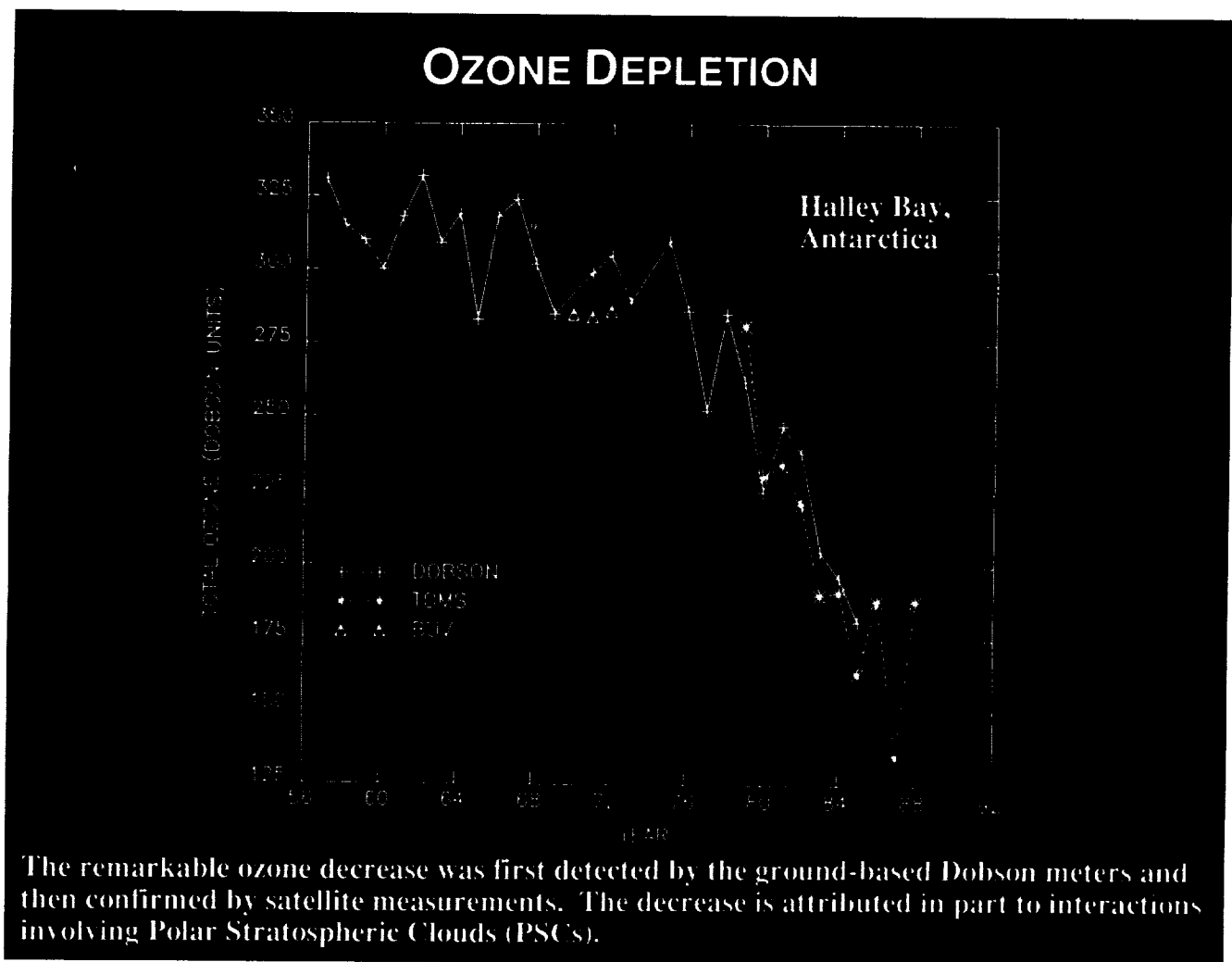


Figure 8. Ozone depletion from 1956 to present. (NASA)

key components and processes of the Earth's biogeochemical cycles.

5. The circulation, surface temperature, wind stress, and sea state, and the biological activity of the oceans.

6. The extent, type, state, elevation, roughness and dynamics of glaciers, ice sheets, snow and sea ice and the liquid equivalent of snow in the global cryosphere.

7. The global rates, amounts and distribution of precipitation.

8. The dynamic motions of the Earth (geophysics) as a whole, including both rotational dynamics and the kinematic motions of the tectonic plates.

Earth: The Overview from Space

The space program gave us our first views of Earth as the blue planet and unique life oasis. Those pictures have had an enormous impact — as evidenced by how often they're used. It shows you the impact of such overview pictures. Figure 4 is a schematic showing the overview of Mission to Planet Earth satellites. In conjunction with our polar orbits, there are satellites planned for geostationary orbits, that is missions that are placed in an orbit that allows continuous monitoring over a particular region of the world. If there is an enormous forest fire or volcano that erupts, we have to keep looking at the same place and for this rather than a polar orbit a stationary orbit is required. The problem with geostationary orbits is that they are higher and more expensive to launch. In order to get a station-

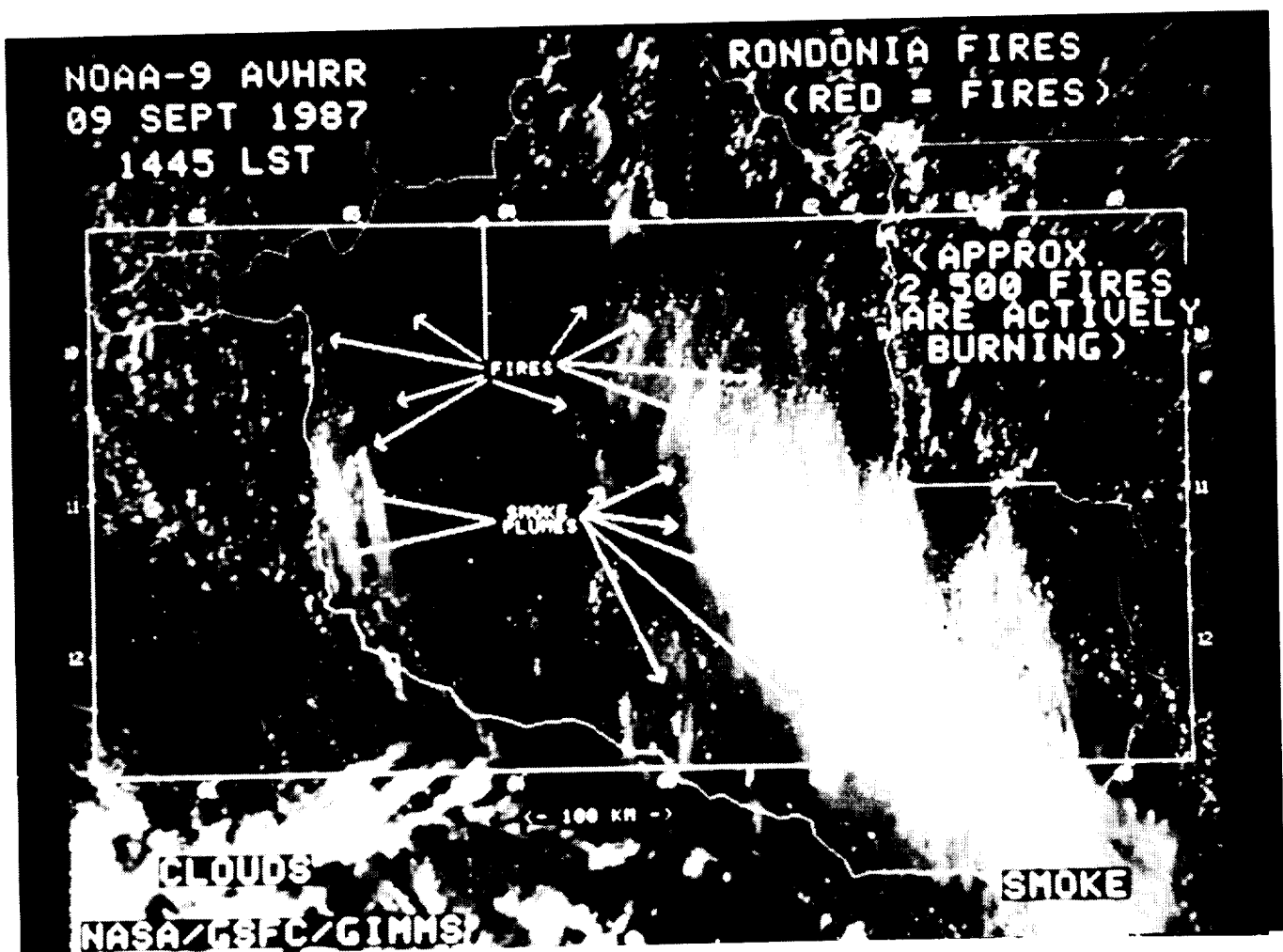


Figure 9. Space view of state of Rondonia, Brazil showing fires from destruction of tropical rainforest. (NASA)

any orbit the satellite has to be 23 thousand miles out from the surface of the Earth.

Since the Space Station *Freedom* will be in equatorial orbit, we are going to attach some instruments to it to look at the tropical belt. The tropics are of particular concern because of the enormous deforestation of the tropical rainforests and desertification of tropical grasslands. Underlying the urgency of programs like EOS is the realization that global change is inevitable and of a different character than ever before. Our biosphere seems to be in stress.

The Earth has always been subject to change from what we know of its geological and life history. What is different about the present time is that

humans now are beginning to add their own impacts to the natural changes because there are so many of us. We are currently some 5.3 billion people on the Earth. Projections show that this could increase to some 10 billion by 2025 and 14 billion by the end of the next century (Figure 5). That is an incredibly powerful vector driving many types of other impacts, such as pressure on natural resources, urbanization, pollution etc. and one which can't be simply slowed down.

I want to underline that EOS is not fundamentally hardware, it is the information system to enable us to understand the Earth system. Until recently, we probably didn't have the capability of doing anything like this mission. We didn't have the

SATELLITE ESTIMATES OF DEFORESTATION

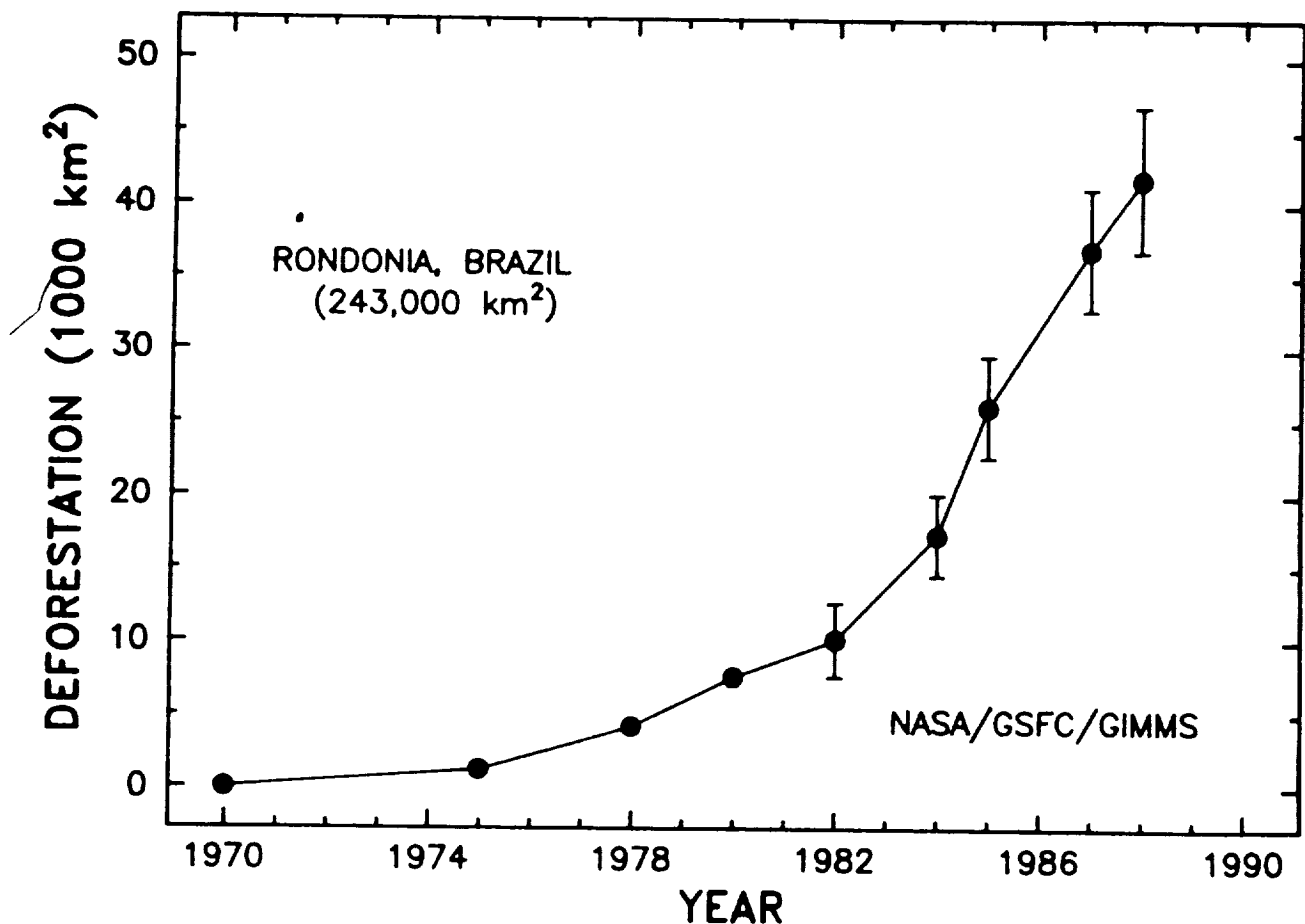


Figure 10. Estimate from space observation of percent loss of forest in Rondonia. (NASA)

computer power we have now. We didn't have all of the technical tools we have now. But we now have no excuse; if we don't do this, or somebody else doesn't do it, it is just because we lack the resolve or are lazy or ignorant or afraid. We certainly have the technical capability now. We must also develop an increasingly interdisciplinary approach to go from data to information to understanding.

We can presently identify pretty obvious major Earth problems. We might call them our generation's "Four Horsemen of the Apocalypse" — acid rain, ozone depletion, global warming and deforestation. These are fueled by the unprecedented rise in human population, and if current trends persist, we haven't seen anything yet. Yet

we don't know other problems that may be coming. These four are just 1989's problems. What may happen in the next five years even if we are able to go ahead with the preparation for EOS when we discover there is a fifth one? It's clear that we are going to have to be able to adequately respond in real time to the unexpected.

Figure 6 shows a graph of increasing carbon dioxide concentrations in the atmosphere and some of the expected consequences. It is perhaps the classical graph that marked our first recognition that there was a very serious problem on Earth. This rise in carbon dioxide is from 1955 to 1985, just a 30 year period. This was originally started by one young man, David Keeling, who went to the top of Mauna Kea in Hawaii and put up a small

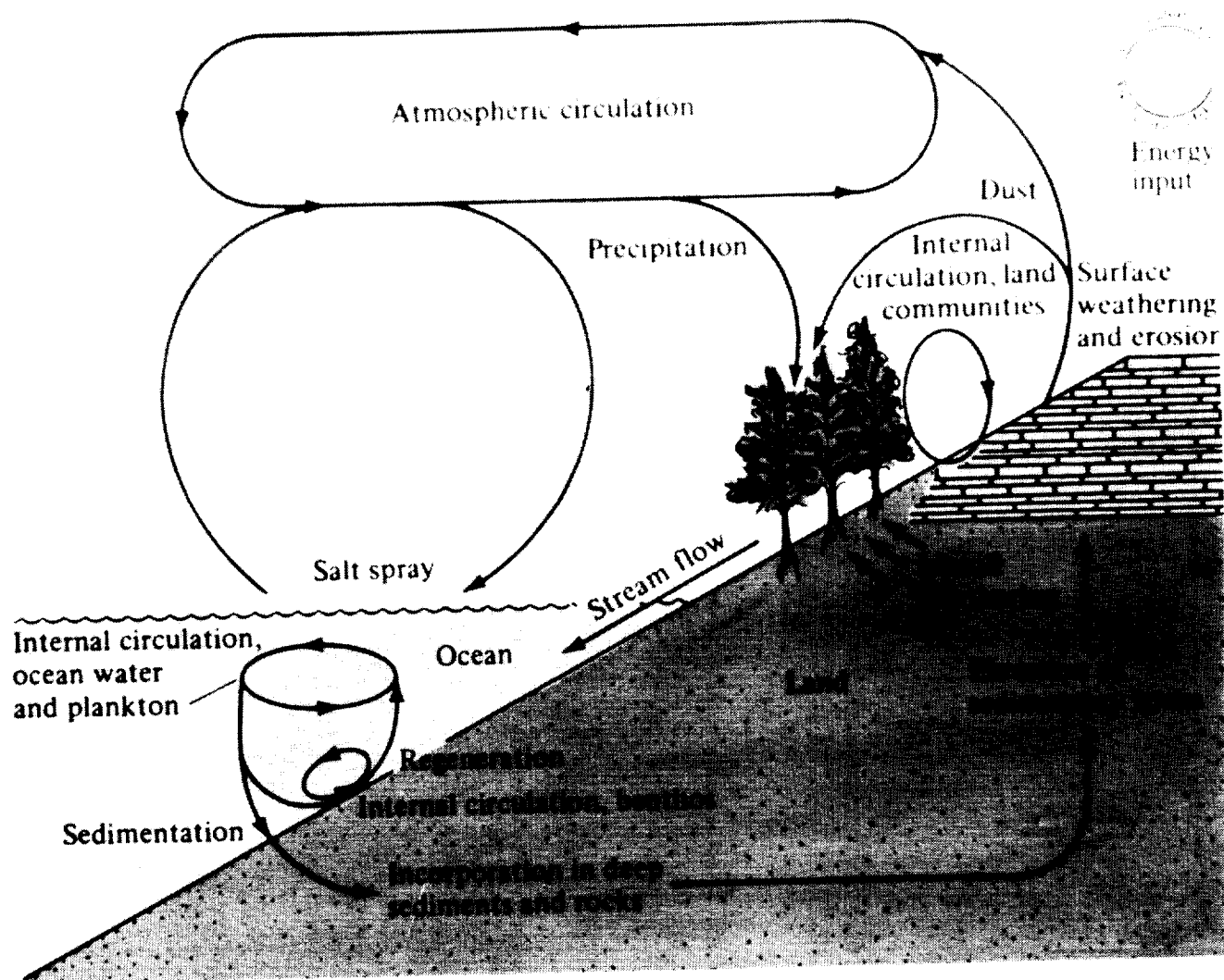


Figure 11. Schematic diagram of interplay of forces determining Earth processes.

sensor and started measuring carbon dioxide in the atmosphere. People thought, when he started reporting his data in the early 1960's, "So what, it doesn't really mean anything. The small amount of carbon dioxide in Earth's atmosphere goes up and down every year, depending on the seasons. It can't be too important." By the late 70's scientists began to realize that the observed rise of about a half of a percent a year could be very serious indeed. I don't want to overemphasize or underemphasize it, we really don't know yet how serious this rise could be. We just don't know the consequences.

Two scenarios have been advanced and modeled by scientists on possible global warming due to the greenhouse effect caused by increasing carbon dioxide in the atmosphere. One is called slow changes and the other is called rapid changes (Figure 7). The latter is a more pessimistic view in which we see a 4-6 degrees C. rise versus the former which results in a 2-4 degrees C. rise in

average temperature over the next century. These increases may not sound like very much, but the last ice age was only 2 degrees C. average temperature colder than our present level. The difference in temperature between where we are now and where we will be in just a hundred years in the most optimistic point of view is about the same as the rise in temperature from the last ice age to now. Our global temperature hasn't changed very much in that long stretch of time. In the most pessimistic view, we could see a 6 degrees rise — or three times as much change. This could have a quite dramatic effect on our climate: the whole western United States is in trouble, north Africa, northern Australia, southwest Asia etc. It is uncertain that this will occur, but it is a least one real possibility that our modelers have worked with.

Figure 8 deals with ozone depletion. We keep hearing about the hole in the ozone layer. So what? What does it mean? The ozone layer protects the biosphere from biologically very potentially damag-

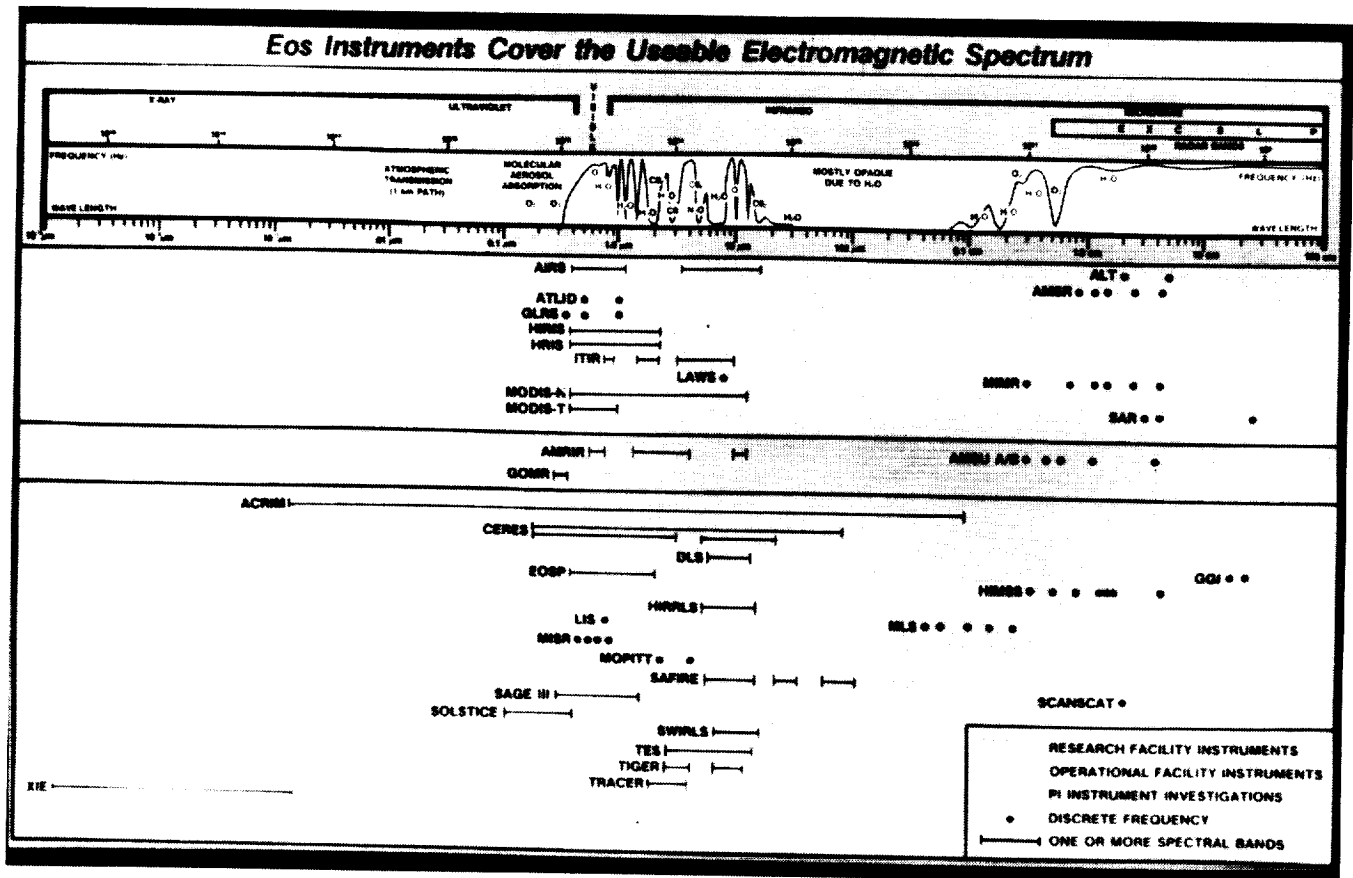


Figure 12. Schematic showing coverage of the electromagnetic spectrum by proposed EOS instruments. (NASA)

ing ultraviolet rays from solar radiation. The depletion of ozone on the Earth from the levels measured in 1956 until the present are quite dramatic. This process is continuing to happen and that is what has us so upset. It hasn't stopped and we don't fully understand it. We do know it is urgent that we find out what is happening to the ozone layer.

If you were an astronaut and flew in the last Shuttle and passed over Brazil, you could look down and see Rondonia, which is a state about the size of Arizona. You would see quite clearly a gridwork of roads where they are cutting the tropical rainforest down. In Figure 9 we have a space view of the state of Rondonia, showing that about a quarter of the state of Rondonia is completely smoke-ridden with approximately 2,500 fires burn-

ing at the same time. If you are on the ground it will look like a scene of great devastation. In fact, the deforestation of Rondonia has currently resulted in a loss of tropical forest from about 40 percent of the total area. Figure 10 graphs the rate at which this deforestation is happening.

Scientists who have been studying this realize they must start putting together models to try to understand some of these problems. We must understand where the Sun plays a role, where the clouds play a role, what does the ocean do, what does the land do, what does the water do? All of that has to be put together. We have never tried to understand this whole Earth as a planet. This EOS mission has many different objectives that cover so many areas dealing with water, energy, biology and

GEOBASED INFORMATION SYSTEM

EXAMPLES OF DATA BASE PARAMETERS

ATMOSPHERIC PARAMETERS

EVAPOTRANSPIRATION

TOPOGRAPHY

CULTURAL SITES

VEGETATIVE COVER/BIOMASS

SOIL MOISTURE

GEOLOGIC STRUCTURES AND SOILS DATA

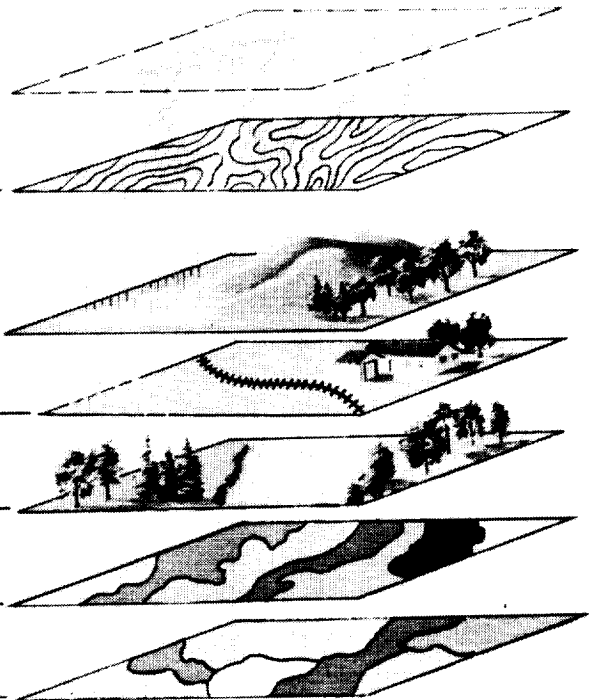


Figure 13. Geobased information system: examples of database parameters. (NASA)

ocean systems. In fact, there are about 500 different things we are going to try to measure dealing with such elements as winds and clouds and volcanoes and sea surface. One thing that makes the Earth so complicated, so much harder to understand than Mars, is that we have an enormous amount of liquid water that changes the whole character of the planet. By comparison, Mars is bone-dry, though it may have large amounts of frozen water below its surface, compared to the Earth. On top of that are the myriad effects of life and additionally the impacts and activities of humans. This planet is so complicated that we are beginning to realize how hard this task of understanding will be (see for example, Figure 11).

Remote sensing instruments that we use have to look down through a complex, layered and often clouded atmosphere. Figure 12 shows a schematic of the electromagnetic spectrum that will be covered by EOS instruments. Both in the visible range

and the microwave range, there are a variety of instruments planned to look down through the atmosphere. Each of the EOS spacecraft have different combinations of instruments to do different jobs and together they mesh together to try to get the total understanding. Each of these instruments is the size of a large wardrobe — much larger than instruments we have flown previously in spacecraft. We need large instruments because the measurements are complicated. One of the problems of the polar mapping process is that it would leave holes in the equatorial region. That is the reason that we want the equatorial mission associated with Space Station *Freedom* to complement EOS.

Figure 13 gives an illustration of the data base parameters. We have to take all of these various pieces and fit it all together. We will receive about a trillion bits of data every day for ten years during EOS. In the language of computer scientists that is a terabyte of data per day. A terabyte of data is

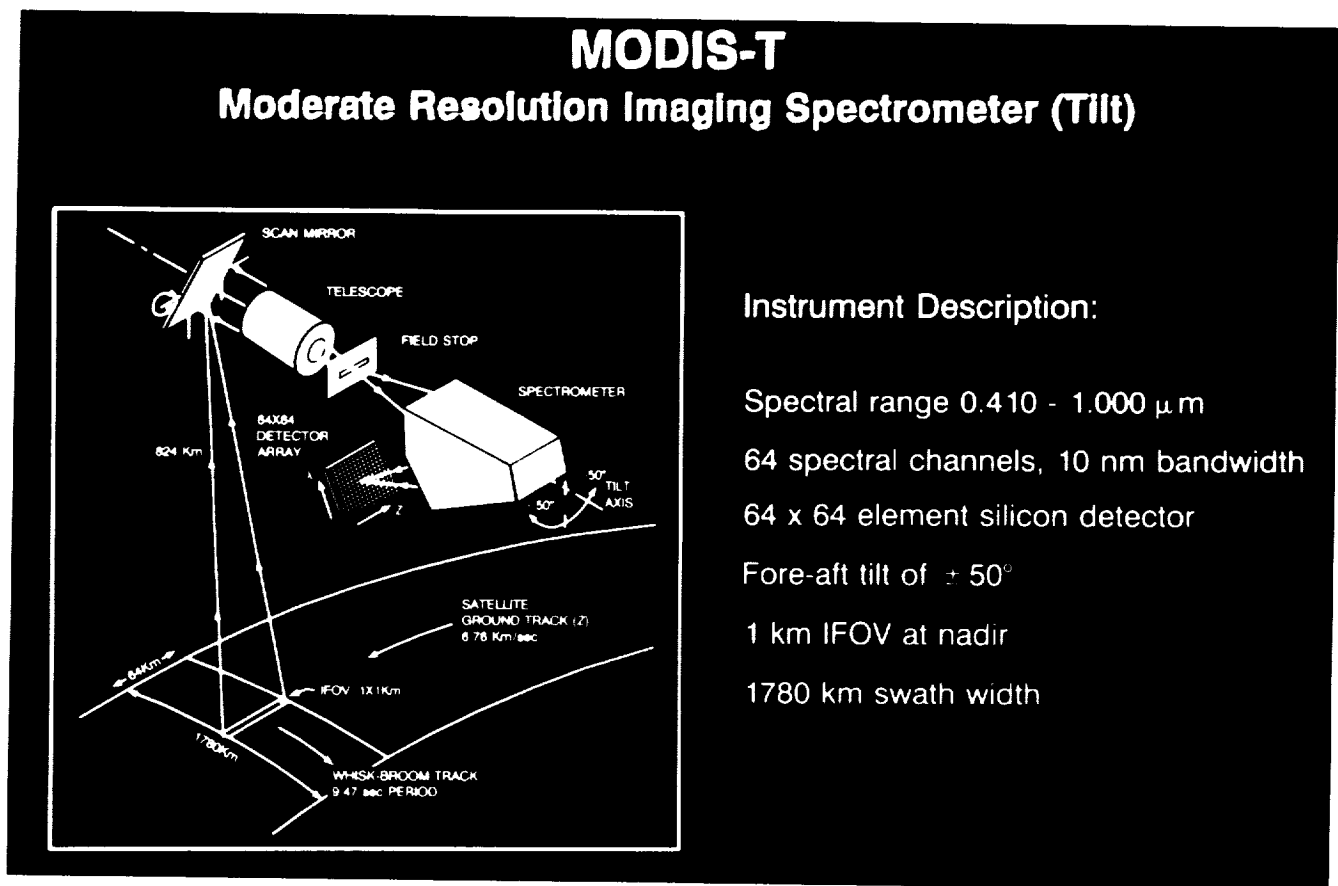


Figure 14. Modis-T Moderate Resolution Imaging Spectrometer. (NASA)

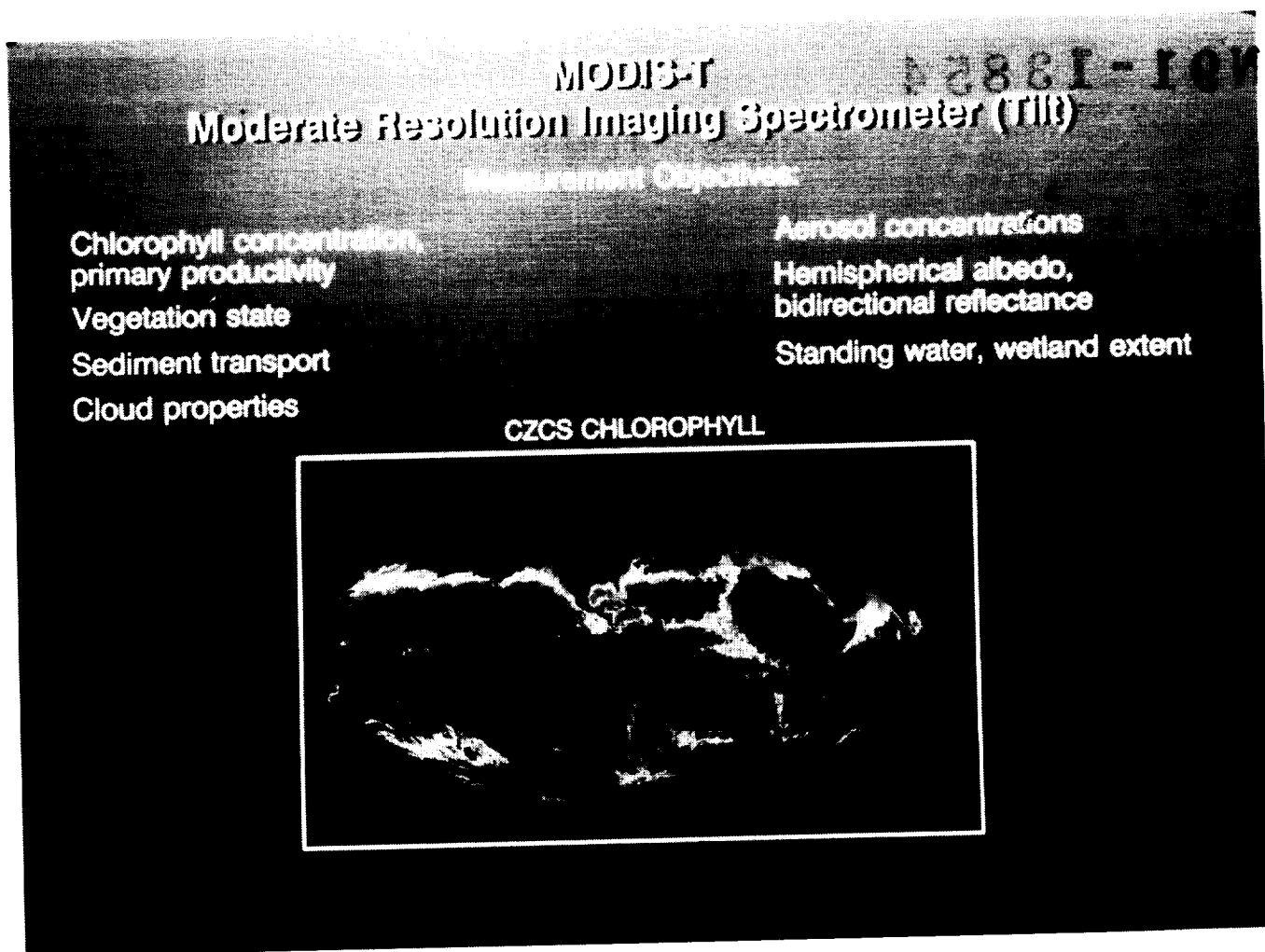


Figure 15. Measurement objectives and type of global map that will be produced by the Modis-T Moderate Resolution Imaging Spectrometer. (NASA)

more data than NASA has accumulated so far to date from all its missions. We will get that every single day. This question of handling of the data may be the greatest single challenge facing EOS. We have two subcontracting firms now examining the question of the data system architecture. We are looking at how we can develop a system to network and make available the data to the scientific community. One thing that is clear is that we must standardize the use of symbols and language so that it can be sent out in a documented and reliable manner. One solution we're looking at is that we employ an artificial intelligence system on board to determine which data is important and which is not.

From the information gathered, EOS is going

to be generating maps. We are going to have to learn to put those data bits and pieces together and understand the whole Earth. We will see during this period enormous numbers of global maps using data generated from the EOS instruments. An example would be the Modis-T Moderate Resolution Imaging Spectrometer (Figure 14). Figure 15 shows the measurement objectives and the type of global map that it will produce.

In summary, the concerns motivating the EOS project planning is that the Earth is changing. It is very likely to affect our weather and climate. We have to understand it. We need more data. This will take a large international effort and EOS is very vital and the next logical step.